High CE technology for HVM EUV source

Hakaru Mizoguchi and Shinji Okazaki / GIGAPHOTON INC.

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Outline

1. **Introduction**
2. **Engineering Test source**
   - 1st Generation (ETS) device: System experiment
     - Operation Data
   - 10Hz device: Critical issue experiment
     - Vaporization experiment
     - Ionization experiment
     - Magnetic mitigation
     - Pre-pulse and high CE
3. **HVM EUV light source**
   - Product roadmap
   - 2nd Generation device: Development status
     - Configuration
     - Latest status
4. **Summary**

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When will we reach the end of the tunnel ?

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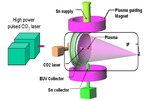
EUV sources

LPP : CO_2 laser and Tin source
- ✓ High power pulsed CO_2 laser
- ✓ Magnetic field plasma mitigation
- ✓ Pre-Pulse plasma technology



Type	LPP
Power (at present) peak/average	104W/21W
Plasma	No electrode
Mitigation	Pre pulse + Magnet
Life limitation	(several 1000 hr)
Remark	・Theoretically no limit ・Engineering works still to be done

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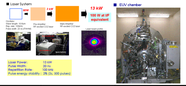
System operation Data (ETS device)



	SPIE 2010 (Feb.2010)	EUV Symposium (Oct.2010)	SPIE2011 (Feb,2011)
EUV power (@ I/F)	69 W	104 W	42 W
EUV power (clean @ I/F)	33 W	50 W	20 W
Duty cycle	20 %	20 %	5%
Max. non stop op. time	>1 hr	<1 hr	>7 hr
Average CE	2.3 %	2.5 %	2.1%
Dose stability :simulation	(+/- 0.15%)		-
Droplet diameter	60mm	60mm	30mm
CO_2 laser power	5.6 kW	7.9 kW	3.6kW

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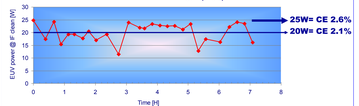
System operation result on ETS

➢ **Long time system operation demonstrated**
- ➢ Operation duration: **7 hours**
- ➢ Droplet: **30 μm diameter**
- ➢ Full repetition rate: 100 kHz
- ➢ In burst clean power: 20W (average) 25W (max)



Conditions;
Control: Droplet position control ON, EUV energy control OFF
CO_2 laser = 3.6kW @ 100kHz
Duty=5% (50msecON, 950msecOFF)

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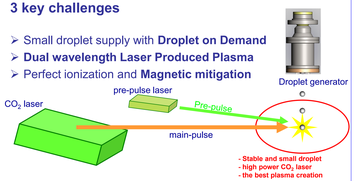
Higher CE challenge more than 5%

3 key challenges

- ➢ Small droplet supply with **Droplet on Demand**
- ➢ **Dual wavelength Laser Produced Plasma**
- ➢ Perfect ionization and **Magnetic mitigation**



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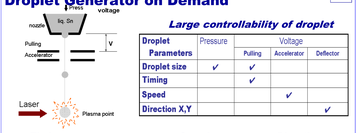
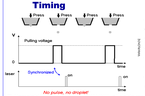
Droplet Generator on Demand

Large controllability of droplet

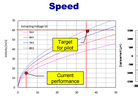


Droplet Parameters	Pressure	Voltage		
		Pulling	Accelerator	Deflector
Droplet size	✓	✓		
Timing		✓		
Speed			✓	
Direction X,Y				✓

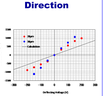
Timing



Speed



Direction



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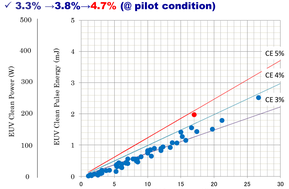
Dual wavelength Laser Produced Plasma

➢ **After CE optimization**
✓ **3.3% →3.8%→4.7% (@ pilot condition)**



■ C **New champion data of CE = 4.7% (May.2012)**

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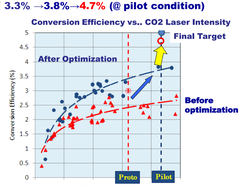
✓ **3.3% →3.8%→4.7% (@ pilot condition)**



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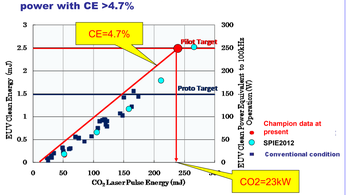
EUV Output Power vs. CO2 Input Power

➢ **We expect 2.5mJ EUV output corresponds to 250W clean power with CE >4.7%**



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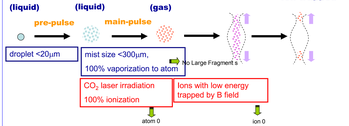
Magnetic mitigation

Collector mirror protection Concept

All Tin atoms should be ionized.
① Magnet field is effective for guiding ions to protect mirror
② All Tin fragments and atoms are needed to be ionized



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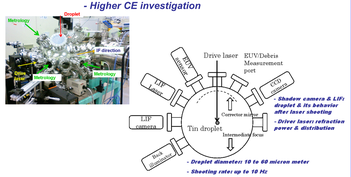
Critical issue investigation with 10Hz device

- Double pulse optimization
- Debris mitigation mechanism
- Higher CE investigation



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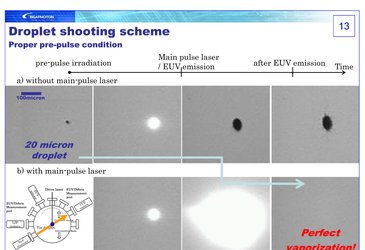
Droplet shooting scheme

Proper pre-pulse condition



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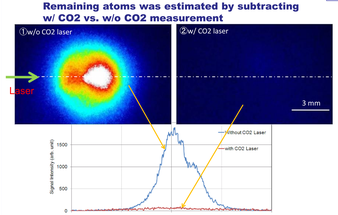
Atom measurement by LIF - 2

Remaining atoms was estimated by subtracting w/ CO2 vs. w/o CO2 measurement



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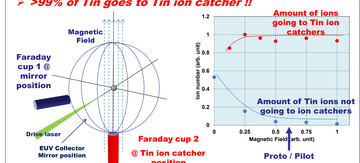
Ion Measurements by Faraday cups

➢ **Amount of ion is measured by Faraday cup**

➢ ***>99% of Tin goes to Tin ion catcher !!***



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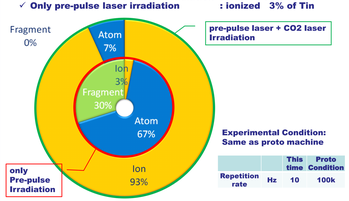
Results Summary

➢ **Tin molecule measurement results**
- ✓ **pre-pulse laser irradiation : ionized 93% of Tin**
- ✓ **Only pre-pulse laser irradiation : ionized 3% of Tin**



Experimental Condition: Same as proto machine

		This time	Proto Condition
Repetition rate	Hz	10	100k

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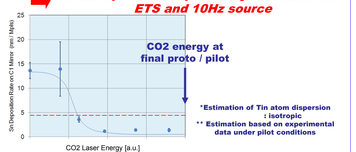
Clean operation feasibility proven

➢ **Estimated deposition and cleaning rates**
- ✓ **Deposition rate: 1.2 nm / Mpls***
- ✓ **Cleaning rate: 4.4 nm / Mpls****

Clean operation is proven by test data with ETS and 10Hz source



*Estimation of Tin atom dispersion : isotropic
** Estimation based on experimental data under pilot conditions

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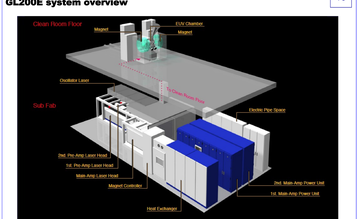
GL200E system overview



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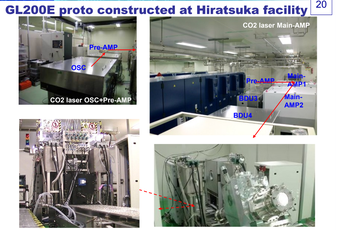
GL200E proto constructed at Hiratsuka facility



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Maximum 7W clean power at Proto system is on line

➢ **EUV light generated at Proto system**

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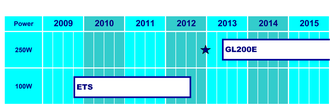
EUV Source product roadmap



➢ **GL200E pilot will be delivered to Scanner maker Q4 2012**
- ✓ **Initially at 50W clean power**
- ✓ **Follow-on upgrade to 250W**

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Summary

- **1st generation integrated setup LPP source (ETS) and 10 Hz device:**
  - Smaller droplet (droplet size reduction from 60μm to 30 μm) extends operation time to 7 hours around 20W(clean power @I/F, 5%duty) level operation.
  - 10Hz experiment proved debris mitigation concept experimentally. That is proper pre-ionization and main ionization make >93% ionization. This technology enables clean light source in combination with magnetic field.
  - 10Hz experiment clarify CE (Conversion Efficiency) improvement, with <20μm droplet we found the region where CE >4.7% and perfect vaporization are simultaneously possible.
- **2nd generation LPP source (GL200E):**
  - Concept of design and outline is reported.
  - Our final goal of GL-200E is 250W and the feasibility is supported by high CE experimental data.
  - We observed 1st EUV light on proto source with 18W equivalent level at present. Next target is 50W level demonstration by 4Q 2012.

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